practical acquaintance with the reactions which they have so often written down, and which in future they will regard with an altogether new interest and delight. Others more advanced are conducting analyses, or perhaps making "combustions"—if in the advanced group, studying organic chemistry. All are intensely busy, and work with a fixed purpose before them. The same quiet activity is noticeable in the different subjects going on in the other rooms. Entering last the physical laboratory on the ground floor, we find the teachers constructing apparatus which, though simple and often rough, is well adapted for teaching purposes. The raw material is provided them, printed instructions are given to each one, and under the direction of Prof. Guthrie, and the gentlemen associated with him, the most useful physical instruments are built up. These instruments are then employed in repeating the experiments seen in the morning lecture, or in making physical measurements wherever it is possible to do so. The homely apparatus, it is true, has not the polish of the instrument-maker, but in delicacy and efficiency is, generally speaking, far better than the teachers could purchase out of the small grants allowed to them for that purpose. With a wise liberality the Department permits each teacher to take home with him, without any charge, all the apparatus he himself has made: and one can easily imagine the pleasure with which these simple and useful instruments are afterwards looked upon and used by those who have made them. Nor is this all; the impulse to sound and practical science teaching is given, and at the same time the hands have been disciplined to useful skill, and the senses trained to accurate observation. After such preparation good use is made by the teachers of the more refined physical instruments which are set before them, but which are beyond their time or power to construct for themselves. It is most instructive to watch one of these men as he makes his first essay, and to trace the growth of his education in manipulative skill and in practical knowledge of his subject. We propose in our next number to go more fully into detail in this matter, and to describe some of the simple physical apparatus made by the teachers.

But the good work done by the Department does not rest here. In addition to giving practical instruction to teachers in short summer courses, free admission to extended courses of lectures and practical instruction in Chemistry, Physics, Mechanics, and Biology at South Kensington was granted to a limited number of teachers and students who intended to become science teachers. The selected candidates received a travelling allowance, and a maintenance allowance of 25*s*. a week while in London. The courses in Chemistry and Biology commenced in October of last year and ended in the early spring, when the courses in Physics and Mechanics began, and these closed at the beginning of this summer. From ten to sixteen teachers in training attended these different classes, and worked daily from 10 to 5 at the subjects they had chosen, in the evening writing up their notes and memoranda. Botany was not included in the foregoing series, but it was not forgotten. In January last the Lords of the Committee of Council on Education gave directions for a practical course on this subject. The course was given by Prof. Thiselton Dyer, and commenced on the 4th of March last, extending over eight weeks. It was attended by twenty-three science teachers and persons intending to become science teachers; these received precisely the same advantages as the teachers in training in the other subjects.

* This refers to last year; the teachers' summer course on Biology has been omitted this session.

The value of such courses as these can hardly be over-estimated, and we trust that no niggardly policy will lead the Government to restrict the great and good work they have begun. We hope there is no cause for apprehension in the apparent neglect of Biology in the summer course given this year, and what seems to us a little diminution of the strength of the staff in another subject. The improvement in the quality of the education given by the science teachers is already making itself felt. The reports of the May examiners for recent years show that "while the general average has been maintained throughout, the instruction had in some subjects decidedly improved." But it will necessarily take a few years to lift up so large a constituency. Surely and slowly it is being done, and the masses of the country are gaining a sound elementary knowledge of science. Whilst the magnificent laboratories of the Universities of Oxford and Cambridge and Dublin are nearly empty, Owens College and the classes under the Department are crowded with active and earnest workers.

The several large educational societies of England have availed themselves for some years past of the benefits offered by the Science and Art Department, with the object of turning the students out of their Training Colleges as thoroughly fitted as possible for their future scholastic career; and the continuance of this system for the future is now further assured by the necessity of their being provided with Government certificates in science in order to secure employment under the London School Board, or indeed at any of the first-class Elementary Schools throughout the country.

An impartial view of the facts we have placed before our readers will show that what the Universities might have done from above, others are doing from beneath. Science, instead of forming the delightful pursuit of the leisure classes, and thence distilling downwards to the workers, is, on the contrary, first becoming an integral part of the education of the toilers of the country. England, in fact, is being scientifically educated from below.

DARWIN ON CARNIVOROUS PLANTS

I.

Insectivorous Plants. By Charles Darwin, M.A., F.R.S., &c. With Illustrations. (London: J. Murray, 1875.)

To have predicted, after the publication of Mr. Darwin's works on the Fertilisation of Orchids and the Movements and Habits of Climbing Plants, that the same writer would hereafter produce a still more valuable contribution to botanical literature, characterised to an even greater extent by laborious industry and critical powers of observation, and solving or suggesting yet more important physiological problems, would have seemed the height of rashness. And yet, had such a prediction been made, it would have been amply justified by the present

volume, one which would alone have established the reputation of any other author, and which will go far to redeem our country from the charge of sterility in physiological work. Much attention has been called recently to the singular subject of "carnivorous plants;" we have had records of useful original work from several quarters in England, the Continent, and America, together with much that has been superficial and worthless; and even the newspapers have discussed the anti-vegetarian habits of some vegetables in the light, airy, and philistine manner in which they are wont to approach "mere scientific" subjects. During the whole of this time, for the last fifteen years, Mr. Darwin has been steadily and quietly at work, collecting materials and recording long series of observations; and now at length has given us their results, completely and finally settling some of the points that have been most in controversy, and raising others which suggest conclusions that will take by surprise even those whose minds have been most open to deviate from the old and narrow paths.

Rather more than one-half of the volume is devoted to the most abundant and readily obtainable of these predatory plants, the common Sundew, *Drosera rotundifolia*; and an epitome of this portion must be first placed before our readers.

Commencing with a description of the well-known leaves and their glandular appendages, or "tentacles," as he terms them, Mr. Darwin has arrived at the conclusion that these latter most probably existed primordially as glandular hairs or mere epidermal formations (trichomes), and that their upper part should still be so considered; but that their lower portion, which alone is capable of movement, consists of a prolongation of the leaf; the spiral vessels being extended from this to the uppermost part. One point which seems to be clearly established is, that it is not sufficient that the substance which excites the movements of the tentacles should merely rest on the viscid fluid excreted from the glands; it must be in actual contact with the gland itself. A statement made by several previous observers (including Prof. Asa Gray on the authority of Mr. Darwin's earlier observations, and the present writer)—that inorganic substances are almost or entirely without effect in producing movement—must now be modified. Although the effect is much less considerable, and the substance is soon released from the embrace of the tentacles; yet such bodies as minute particles of glass undoubtedly possess the power of irritation. While it is the glands or knobs at the extremities of the tentacles, and a very small part of the upper portion of the pedicels, which alone are sensitive or irritable, the actual inflection takes place only in the lowermost portion of the pedicel, causing a bending of the tentacle; and the irritation is conducted from the tentacle actually excited to the neighbouring ones, or to all those on the leaf, in such a manner as to cause them to bend towards the object which produces the excitement. One of the most striking of the series of observations here recorded is that which describes the affixing of exciting particles on glands at two different portions of a leaf of *Drosera*, the result being that all the tentacles near each of these two points were directed towards them, "so that two wheels were formed on the disc of the same leaf, the pedicels of the tentacles forming the spokes, and the glands united in a mass" over the irritated tentacle which represented the axle; the precision with which each tentacle pointed to the irritating particle was wonderful. What makes this result the more extraordinary is that "some of the tentacles on the disc, which would have been directed to the centre had the leaf been immersed in an exciting fluid (as in Fig. 1), were now inflected in an exactly opposite direction, viz., towards the circumference. These tentacles, therefore, had deviated as much as 180° from the direction which they would have assumed if their own glands had been stimulated, and which may be considered as the normal one." As the author remarks, "we might imagine that we were looking at a lowly organised animal seizing prey with its arms." Indeed, the whole description of Mr. Darwin's researches after the tissue that conducts this irritation reminds one of experiments on the motor and sensitive nerves of animals; and we commend the subject to the serious attention of the Royal Commission now sitting to investigate the subject of vivisection. Mr. Darwin compares this movement to the curvature displayed by many tendrils towards the side which is touched; but the comparison appears to us to fail, from the fact that the movement of tendrils is a function of growth, they being sensitive to contact or pressure only so long as they are in a growing state; which is not the case with the tentacles of *Drosera*. One of the most extraordinary of the statements made by trustworthy observers with regard to the sensitiveness of these tentacles is not, however, confirmed by Mr. Darwin. Mrs. Treat (*American Naturalist*, Dec. 1873) asserts that when a living fly was pinned at a distance of half an inch from the leaves of the American species *D. filiformis*, the leaves bent towards it and reached it in an hour and twenty minutes, a phenomenon inexplicable on any theory which would account for the transmission of the irritation from one tentacle to another. Mr. Darwin states, on the contrary, that when pieces of raw meat were stuck on needles and fixed as close as possible to the leaves, but without actual contact, no effect whatever was produced. The minuteness of the solid particles which produced sensible inflection was a matter of great surprise. Particles perfectly inappreciable by the most sensitive parts of the human body, as the tip of the tongue—a fragment of cotton weighing $\frac{1}{8000}$, and of hair weighing $\frac{1}{78000}$ of a grain—caused the tentacles with which they were in contact to bend. Our author remarks that "it is extremely doubtful whether any nerve in the human body, even if in an inflamed condition, would be in any way affected by such a particle supported in a dense fluid, and slowly brought into contact with the nerve; yet the cells of the glands of *Drosera* are thus excited to transmit a motor impulse to a distant point, inducing movement;" and he adds justly, that "hardly any more remarkable fact than this has been observed in the vegetable kingdom." The only substance which appears to be altogether without effect in producing inflection is drops of rain-water; a singular exception paralleled by the case of certain climbing plants whose excessively sensitive tendrils are irritable to every sort of object which touches them except rain-drops.

The inflection of the base of the tentacle is accompanied by a change in the molecular condition of the

protoplasmic contents of the cells of the gland and of those lying immediately beneath it; though the two phenomena are not necessarily connected with one another. If the tentacles of a young but mature leaf that has never been excited or become inflected, are examined, the cells forming the pedicels are seen to be filled with a homogeneous purple fluid, the walls being lined with a layer of colourless circulating protoplasm. If a tentacle is examined some hours after the gland has been excited by repeated touches, or by an inorganic or organic particle placed on it, or by the absorption of certain fluids, the purple matter is found to be aggregated into masses of various shapes suspended in a nearly or quite colourless fluid. This change commences within the glands, and travels gradually down the tentacles; and the aggregated masses of coloured protoplasm are perpetually changing

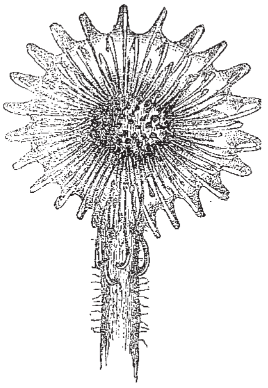

FIG. 1.—(*Drosera rotundifolia.*) Leaf (enlarged) with all the tentacles closely inflected, from immersion in a solution of phosphate of ammonia (one part to 87,500 of water).

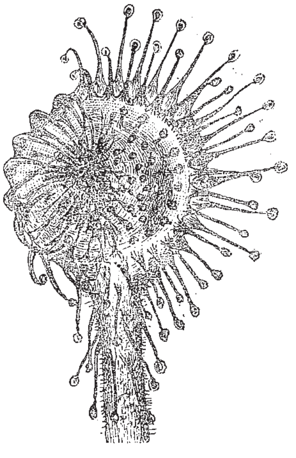

FIG. 2.—(*Drosera rotundifolia.*) Leaf (enlarged) with the tentacles on one side inflected over a bit of meat placed on the disc.

their form, separating, and again uniting. Shortly after the tentacles have re-expanded in consequence of the removal of the exciting substance, these little coloured masses of protoplasm are all re-dissolved, and the purple fluid within the cells becomes as homogeneous and transparent as it was at first. This process of aggregation is independent of the inflection of the tentacles and of increased secretion from the glands; it commences within the glands, and is transmitted from cell to cell down the whole length of the tentacles, being arrested for a short time at each transverse cell-wall. The most remarkable part of the phenomenon is that even in those tentacles which are inflected, not by the direct irritation of their glands, but by an irritation conducted from other glands on the leaf, this aggregation of the protoplasm still commences in the cells of the gland itself.

Some who admit the reality of the phenomena now described, have still doubted the digestive power ascribed to the leaves of the Sundew, believing that the apparent absorption of the organic substances in contact with the glands is due rather to their natural decay. This question is, however, entirely set at rest by Mr. Darwin's observations. The action of the secretion from the glands on all albuminous substances—for it is by these only among fluids that inflection of the tentacles is excited—is precisely the same as that of the gastric juice of animals. The secretion of the unexcited glands is neutral to test-papers; after irritation for a sufficiently long period it is distinctly acid. A very careful analysis by Prof. Frankland of the acid thus produced indicated that it was probably propionic, possibly mixed with acetic and

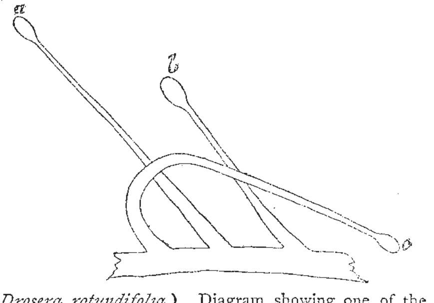

FIG. 3.—(*Drosera rotundifolia.*) Diagram showing one of the exterior tentacles closely inflected; the two adjoining ones in their ordinary position.

butyric acids; and the fluid, when acidified by sulphuric acid, emitted a powerful odour similar to that of pepsin. If an alkali is added to the fluid, the process of digestion is stopped, but immediately recommences as soon as the alkali is neutralised by weak hydrochloric acid. Mr. Darwin believes that a ferment of a nature resembling that of pepsin is secreted by the glands, but not until they are excited by the absorption of a minute quantity of already soluble animal matter; a conclusion which is confirmed by the remarkable fact observed by Dr. Hooker, that the fluid secreted by the pitchers of *Nepenthes* entirely loses its power of digestion when removed from

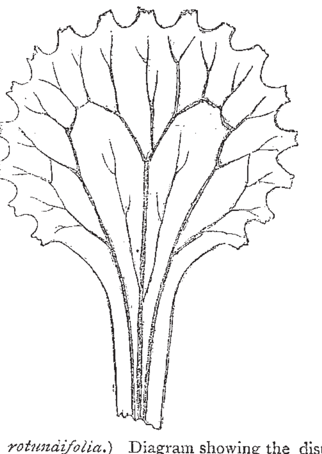

FIG. 4.—(*Drosera rotundifolia.*) Diagram showing the distribution of the vascular tissue in a small leaf.

the pitcher in which it is produced. It is one of the many extraordinary facts connected with this subject that the tentacles of the leaves of *Drosera* retain their power of inflection and digestion long after the separation of the leaves from their parent plant.

As might naturally be expected, salts of ammonia are among the substances which have the most powerful effect on the leaves of *Drosera*; but the excessively minute quantities which are efficacious will probably be

as astonishing to everyone else as they were to Mr. Darwin himself. From a most carefully conducted series of experiments from which every possible source of error seems to have been eliminated, it appears that the absorption by a gland of $\frac{1}{268800}$ of a grain of carbonate of ammonia (this salt producing no effect when absorbed through the root) is sufficient to excite inflection and aggregation of the protoplasm. With nitrate of ammonia a similar effect is produced by the $\frac{1}{691200}$ of a grain; while the incredibly small quantity of $\frac{1}{19760000}$ of a grain of phosphate of ammonia produces a like effect. Mr. Darwin believes that carbonate of ammonia is also absorbed in the gaseous state by the tentacles; but we venture to think that the evidence on this point is not conclusive. In both the experiments which he records the air surrounding the plant was more or less humid, and the effect was much more intense in the one where the air was the dampest, indicating apparently that the inflection was due to the absorption of the extremely soluble gas by the moisture which was in contact with the tentacles. This would also afford an explanation of what he regards as "a curious fact, that some of the closely adjoining tentacles on the same leaf were much, and some apparently not in the least, affected," if we suppose that they were clothed with larger and smaller amounts of moisture. The view that the glands have no power of absorbing gases or effluvia receives confirmation from the failure of the attempt to induce inflection or aggregation by the affixing of particles of meat in close proximity to the tentacles, but without actual contact.

We cannot follow Mr. Darwin through his exhaustive series of experiments on the effects of various solutions of mineral salts, acids, and poisons, on the leaves of *Drosera*. With organic fluids the aggregation of the protoplasm and inflection of the tentacles furnish a most delicate and unerring test of the presence of nitrogen. The effect of inorganic salts and poisons can by no means be inferred from the effect of the same substances on living animals, nor from their chemical affinity. Nine salts of sodium all produced inflection, and were not poisonous except when given in large doses; while seven of the corresponding salts of potassium did not cause inflection, and some of these were poisonous. This corresponds to the statement of Dr. Burdon Sanderson, that sodium salts may be introduced in large quantities into the circulation of mammals without any injurious effects, whilst small doses of potassium salts cause death by suddenly arresting the movements of the heart. Benzoic acid, even when so weak as to be scarcely acid to the taste, acts with great rapidity and is highly poisonous to *Drosera*, although it is without marked effect on the animal economy. The poison of the cobra, on the other hand, so deadly to all animals, is not at all poisonous to *Drosera*, although it causes strong and rapid inflection of the tentacles, and soon discharges all colour from the glands.

The last point of investigation is the mode of transmission and nature of the conducting tissue of the motor impulse from one tentacle to another. It has been already stated that the seat of irritability is limited to the glands themselves and a few of the uppermost cells of the pedicels, the blade of the leaf itself not being sensitive to any stimulant. In order to be conveyed from one tentacle to another, the impulse has therefore to be transmitted down nearly the whole length of the pedicel; and it appears to be conveyed from any single gland or small group of glands through the blade to the other tentacles more readily and effectually in a longitudinal than in a transverse direction. It can be shown that impulses proceeding from a number of glands strengthen one another, spread further, and act on a larger number of tentacles than the impulse from any single gland. The phenomenon already alluded to, of the aggregation of the protoplasm in a tentacle incited indirectly by the irritation of other glands on the leaf—this aggregation advancing not upwards, but downwards, in each tentacle—is spoken of by Mr. Darwin as partaking of the nature of those actions which in the nervous systems of animals are called reflex. The existence of such a phenomenon—of which this is the only known instance in the vegetable kingdom—is one of the most extraordinary points brought out by these investigations. It will be recollected that the transmission of the motor impulse in the sensitive leaves of *Mimosa* is in a precisely opposite direction, travelling upwards from the base to the apex of those pinnæ which are indirectly irritated in consequence of the direct irritation of other pinnæ of the same leaf. The arrangement and direction of the fibro-vascular bundles in the leaves of *Drosera* are shown in Fig. 4; and Mr. Darwin's inquiries were first directed to solve the question whether the impulse was conveyed through the vascular system; but he came to the conclusion that it is not sent, at least exclusively, through the spiral vessels or through the tissue immediately surrounding them. He believes, on the contrary, that the conducting tissue is the parenchyma or cellular tissue of the mesophyll of the leaf; and that it is chiefly delayed by the obstruction offered by the cell-walls through which it has to pass; the transmission of the impulse being indicated by the phenomenon of aggregation of the protoplasm, which is transmitted gradually from cell to cell.

A few other species of *Drosera* were examined, but presented no special phenomena of interest; and the remainder of the volume is occupied by the narrative of researches on other carnivorous plants, a review of which we must defer to a future number.

Alfred W. Bennett

(*To be continued.*)

PERCY'S METALLURGY

Metallurgy: Introduction, Refractory Materials and Fuel. By John Percy, M.D., F.R.S. (London: J. Murray, 1875).

THIS valuable work is not merely a new edition of the volume previously published by its distinguished author, for it contains more than 350 pages of fresh matter, and several articles on subjects which were not treated of originally. Dr. Percy's "Metallurgy" is so well known as the standard book in this country that it may be well to indicate as succinctly as possible the differences between the present volume and the portion of the one published in 1861, which was devoted to refractory materials and fuel.

Much information has been added to the section which